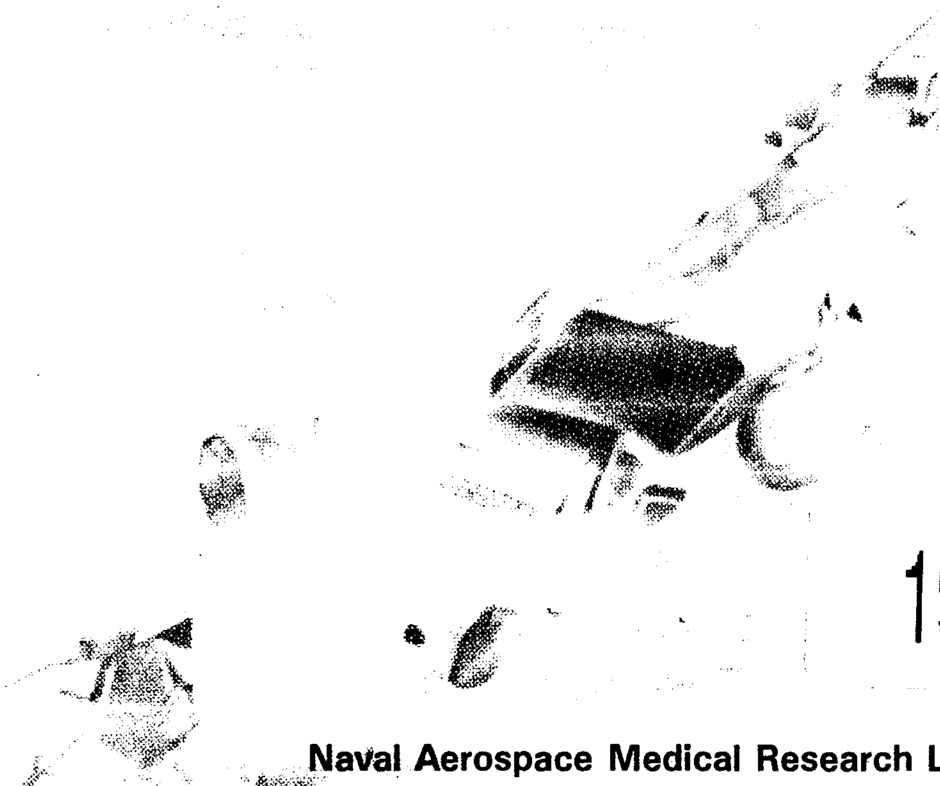
Naval Aerospace Medical Research Laboratory

NAMRL Technical Memorandum 95-2

SOUND ATTENUATION AND SPEECH INTELLIGIBILITY OF A MODIFIED ACTIVE NOISE REDUCTION (ANR) HEADSET FOR USE BY P3-C SENSOR OPERATORS

C. E. Williams, D. W. Maxwell, and G. B. Thomas



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J. C. PATEE, CAPT, MSC USN
Commanding Officer

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The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government.

Volunteer subjects were recruited, evaluated, and employed in accordance with the procedures specified in the Department of Defense Directive 3216.2 and Secretary of the Navy Instruction 3900.39 series. These instructions are based upon voluntary informed consent and meet or exceed the provisions of prevailing national and international guidelines.

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ABSTRACT

Sound attenuation and speech intelligibility evaluations were conducted on a modified active noise reduction (ANR) headset being considered for use by sensor operators in Navy P3-C aircraft. Measurements were obtained on 10 male ensigns in the Naval Aviation Flight Training Program. A comparison of the sound attenuation values obtained with the ANR "on" (combined passive and active attenuation) to values obtained with the ANR "off" (passive attenuation) revealed 10-15 dB greater attenuation at 125, 250 and 500 Hz, and 1-5 dB less attenuation at 1000 and 2000 Hz. Speech intelligibility scores obtained with the ANR "on" were 10% greater than scores obtained with the ANR "off" at the two highest noise levels (110 and 115 dB SPL). The results of the evaluations demonstrated that ANR technology could prove beneficial to sensor operators in P3-C acoustical environments. Improved low-frequency noise attenuation should enhance sensor operator performance in monitoring low-frequency acoustical signals and decrease the likelihood that operators would sustain auditory fatigue during typical long-duration flights. The results were instrumental in the decision to proceed with the further development and procurement of the headset for use by sensor operators in the Navy's P3-C community.

INTRODUCTION

High levels of noise present at sensor operator stations in Navy P3-C aircraft interfere with the specialized acoustic monitoring tasks that the sensor station operators must perform (1). Overall ambient sound pressure levels ranging from 89 to 118 db during different flight profiles (2) can degrade operator performance and produce auditory fatigue during typical long-duration flights (Hollis, R., Naval Air Warfare Center Aircraft Division, Patuxent River, MD, Personal communication, 1994). The lack of sufficient noise suppression degrades overall system effectiveness (1).

At the request of the Naval Air Warfare Center Aircraft Division, Patuxent River, Maryland (3), we conducted sound attenuation and speech intelligibility evaluations of a modified active noise reduction (ANR) headset (Bose model PRU-57/P) being considered for use by sensor operators in Navy P3-C aircraft. A photograph of the modified headset is shown in Fig. 1. This technical memorandum documents the results of our evaluations.

METHODS

Subjects

Ten male ensigns in the Naval Aviation Flight Training Program served as volunteer subjects for both the sound attenuation tests and the speech intelligibility tests. All of the subjects had hearing threshold levels of 20 dB or less at the standard audiometric test frequencies.

Sound Attenuation

Real-ear Attenuation. Real-ear attenuation measurements were obtained in the laboratory's Real Ear Attenuation Test Facility in accordance with American National Standard ANSI S12..6-1984 (4).

Objective Real-ear Attenuation. Microphone-in-real-ear (MIRE) measurements were obtained in a semireverberant test chamber. A Knowles miniature microphone was placed at the outer end of a Silaflex earplug that was inserted into the subject's ear. The wire to the microphone was small enough so as not to interfere with the seal of the headset earcups, and the microphone and wire were secured so that the microphone remained relatively fixed as the headset was donned and doffed. Figure 2 shows one of the test subjects wearing the headset in the semireverberant test chamber (prior to being seated for the MIRE measurements).

A one-third octave band analysis of the microphone's output was first obtained without the headset being worn as the subject was seated in a broadband noise environment (108 dB SPL). Following free-field (i.e., unattenuated) measurements, the subject donned the headset, and one-third octave band analyses were obtained with the ANR system "off" and the ANR system "on" (attenuated measurements). The procedure was repeated three times for each ear, and the headset was donned and doffed on each occasion.

Noise-level measurements obtained with the headset on (ANR "off") were subtracted from the unattenuated (free-field) measurements to determine the amount of "passive" attenuation. Combined "passive" and "active" attenuation was determined by subtracting the noise-level measurements obtained with the headset on (ANR "on") from the unattenuated noise-level measurements. Means and standard deviations were calculated for the various measurements.

Speech Intelligibility

Speech Materials. The speech intelligibility test employed was the NAMRL-developed Tri-Word Modified Rhyme Test (TMRT) (5,6), a modification of the Modified Rhyme Test (7). The subject's task was

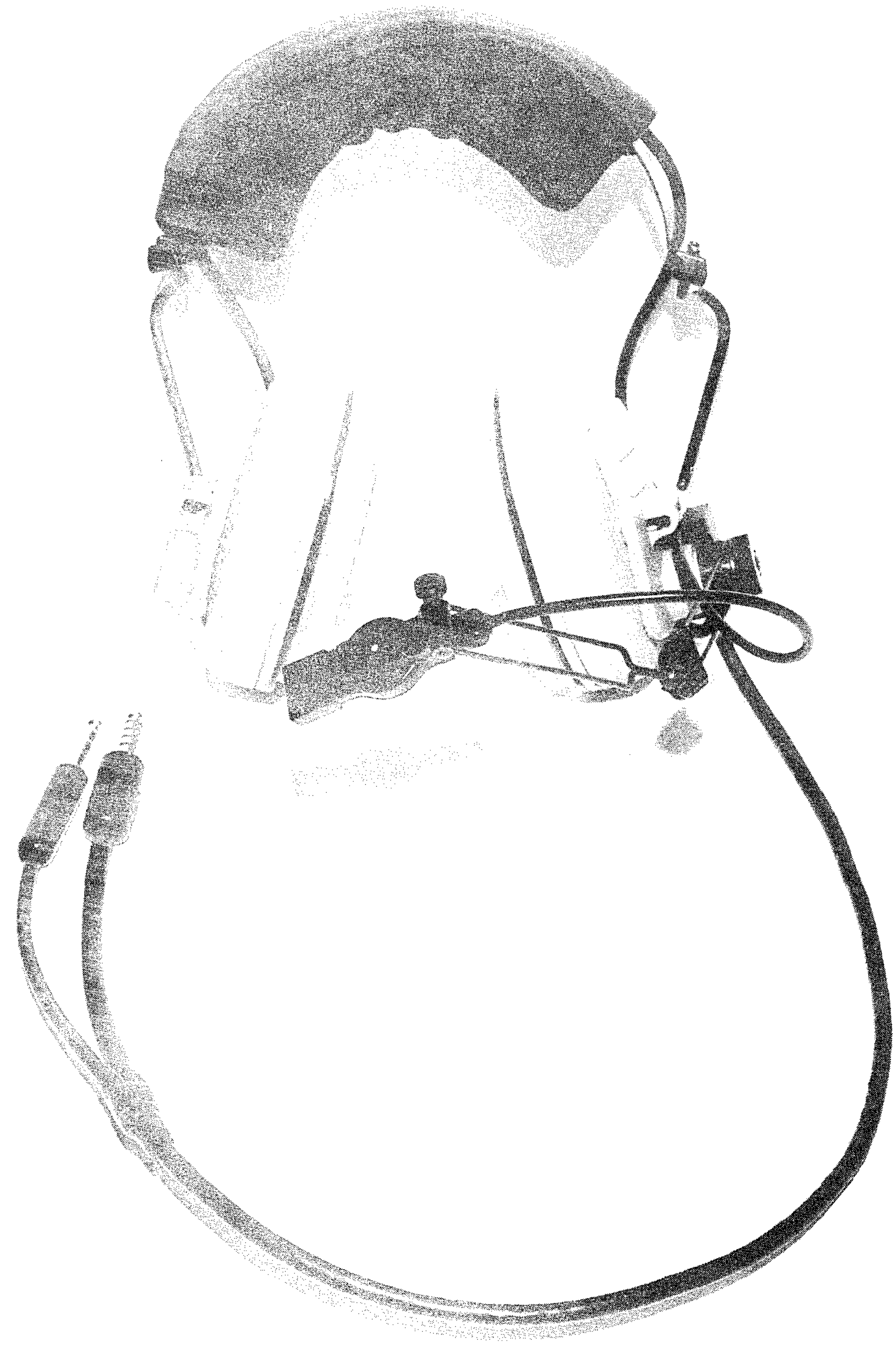

Figure 1. Modified Bose Model PRU-57/P active noise reduction headset.

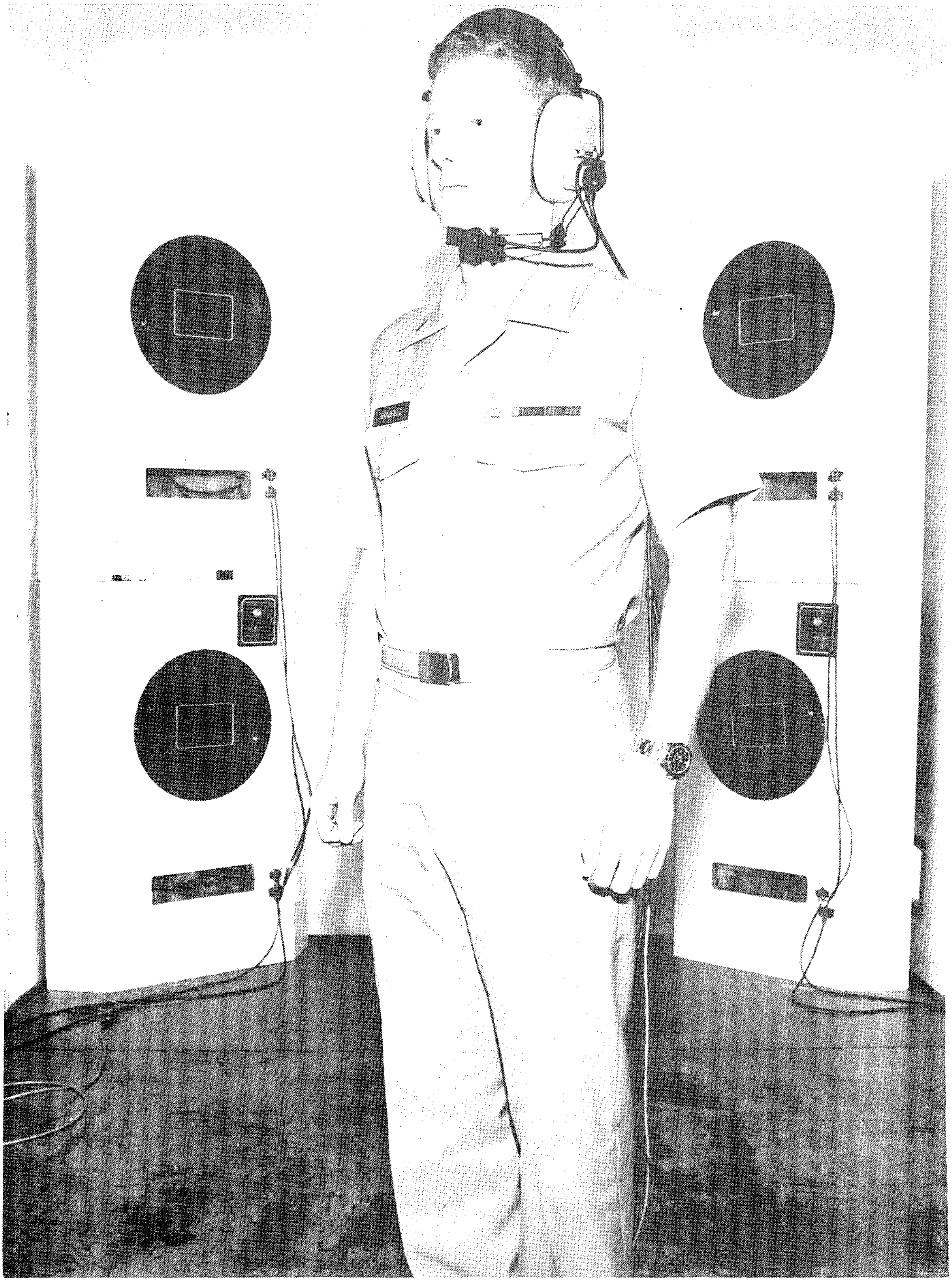

Figure 2. Test subject wearing modified ANR headset in semireverberant test chamber.

to identify tape-recorded target words spoken in a carrier phrase. For example: "One, do you read ___ ___ ___, Over?" "Two, do you read ___ ___ ___, Over?" For each of three target words in a given test message (17 test messages per test), the subject's response form showed six rhyming alternatives from which the correct word was to be identified. A sample response form is shown in Appendix A.

Procedure. The subject was seated in the center of a semireverberant test chamber, which had a uniform sound field. After the subject donned the headset, noise was introduced into the test chamber. The subject was instructed to manipulate the headset until the noise was minimal with the ANR system "off" and there was no audible instability when the system was switched "on."

For each ANR condition, "on/off," two recorded TMRT lists (male speaker with General American speech) were presented to the subjects under three noise level conditions (95, 105, and 115 dB SPL), one speech level condition (85 dB SPL), and two ANR conditions ("off" and "on"). Subsequent speech intelligibility measurements were also obtained on six additional subjects in the presence of 100- and 110-dB noise (85-dB speech) and three additional subjects in the presence of 110- and 115-dB noise (90-dB speech). Figure 3 shows one of the test subjects responding to test messages being presented via the ANR headset.

Response sheets were scored to identify the number of misidentified target words for each of the ANR "on/off" noise-level conditions. Results were tabulated and calculations performed to yield percentage correct scores and standard deviations.

RESULTS

Sound Attenuation

Mean sound-attenuation values and standard deviations obtained via the two types of measurements (real-ear and objective real-ear) are summarized in Table 1. Graphical presentations of the objective real-ear attenuation values are shown in Figs. 4-7. Figures 4 and 5 show comparisons of combined "active/passive" attenuation versus "passive" attenuation for the left and right earcups, respectively. Figure 6 shows a comparison of left earcup versus right earcup "passive" attenuation. Figure 7 shows a comparison of left earcup versus right earcup "active" attenuation. Individual subject data obtained via the different types of attenuation measurements are shown in Appendices B and C.

Speech Intelligibility

The results of the speech intelligibility tests, mean percentage correct Tri-Word Modified Rhyme Test (TMRT) scores and standard deviations, are shown in Table 2. Results of the additional speech intelligibility tests conducted on the two groups of limited subjects (n = 6 and n = 3) are shown in Table 3. Graphical presentations of the results are shown in Figs. 8 and 9. A summary of subjective comments made by the test subjects following the speech intelligibility testing is shown in Appendix D.

DISCUSSION

Sound Attenuation. A comparison of the objective real-ear attenuation (MIRE) values obtained with the ANR "on" (combined passive/active attenuation) to values obtained with the ANR "off" (passive attenuation) revealed 10-15 dB greater attenuation at 125, 250, and 500 Hz, and 1-5 dB less attenuation at 1000 and 2000 Hz. The improved low-frequency attenuation afforded by the modified headset in the ANR "on" mode should prove beneficial to sensor operations monitoring low-frequency signals. This could be verified by having sensor operators perform selected auditory monitory tasks while wearing the headset in both the ANR "off" and ANR "on" modes (either in a simulator or during field testing). The decrease in attenuation at 1000 Hz and 2000 Hz, while small, would undoubtedly affect speech intelligibility to some degree as 1000 and 2000 Hz are in the speech-frequency range (500 to 4000 Hz).

Figure 3. Test subject responding to test messages being presented via the ANR headset.

Table 1. Mean Measurements of Sound Attenuation (in dB). Standard deviations (SD) are shown in parentheses.

Type of measurement	One-third octave band center frequency (Hz) 125	250	500	1000	2000	3150	4000	6300	8000
Real ear	13.5	17.8	18.7	25.4	33.6	38.5	41.5	40.2	39.9
	(3.2)	(4.2)	(2.9)	(3.8)	(3.3)	(4.2)	(2.4)	(2.6)	(2.7)
Obj. Real Ear "Passive"									
Left Ear	7.7	18.6	20.5	30.2	31.3	37.9	42.0	40.1	39.2
	(2.2)	(1.9)	(2.0)	(1.9)	(3.3)	(2.3)	(2.4)	(2.0)	(2.5)
Right Ear	5.0	17.0	18.1	29.9	29.8	36.7	42.1	38.3	37.3
	(1.8)	(3.2)	(1.2)	(2.0)	(3.3)	(3.1)	(3.3)	(2.2)	(1.8)
Obj. Real Ear "Passive" & Active"									
Left Ear	22.7	32.9	30.8	25.6	30.4	37.8	41.6	39.5	39.0
	(2.3)	(1.8)	(1.9)	(2.3)	(3.2)	(2.5)	(1.9)	(2.6)	(2.7)
Right Ear	18.5	30.5	28.1	24.8	28.0	35.5	41.3	38.3	37.1
	(1.8)	(2.2)	(1.4)	(1.9)	(3.4)	(3.0)	(3.1)	(2.2)	(1.9)

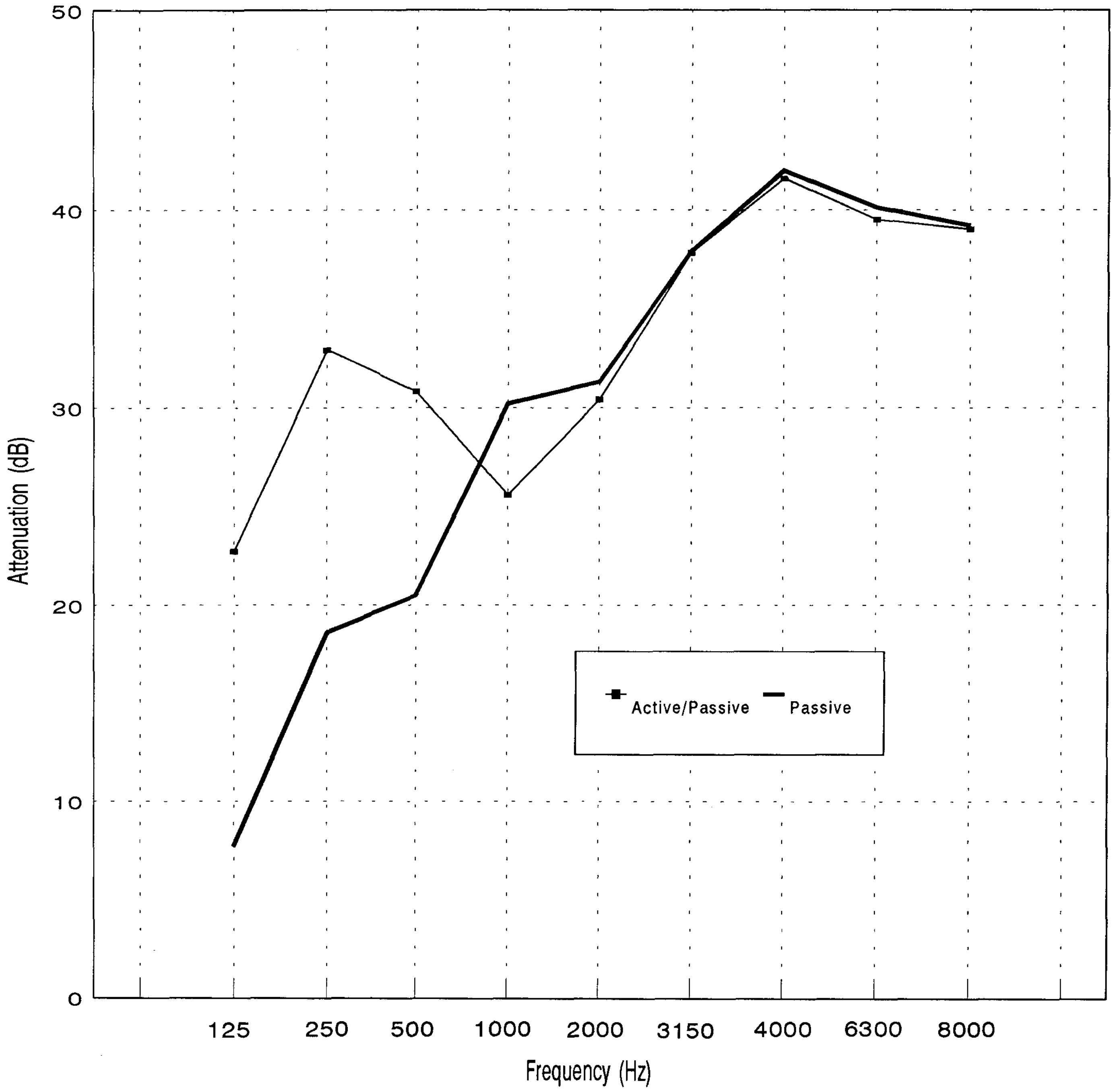

Figure 4. Comparison of combined active/passive attenuation versus passive attentuation - left earcup.

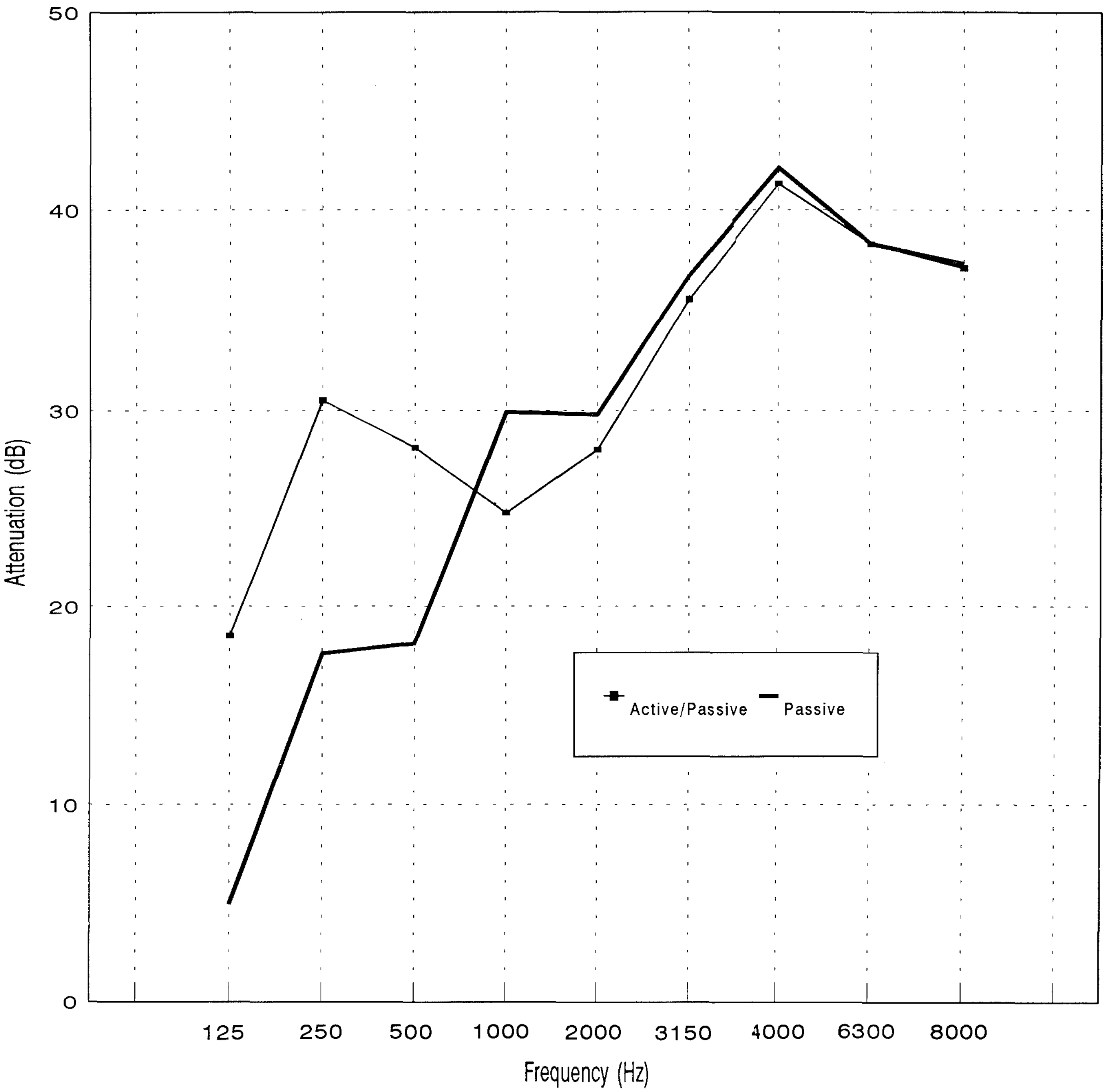

Figure 5. Comparison of combined active/passive attenuation versus passive attenuation - right earcup.

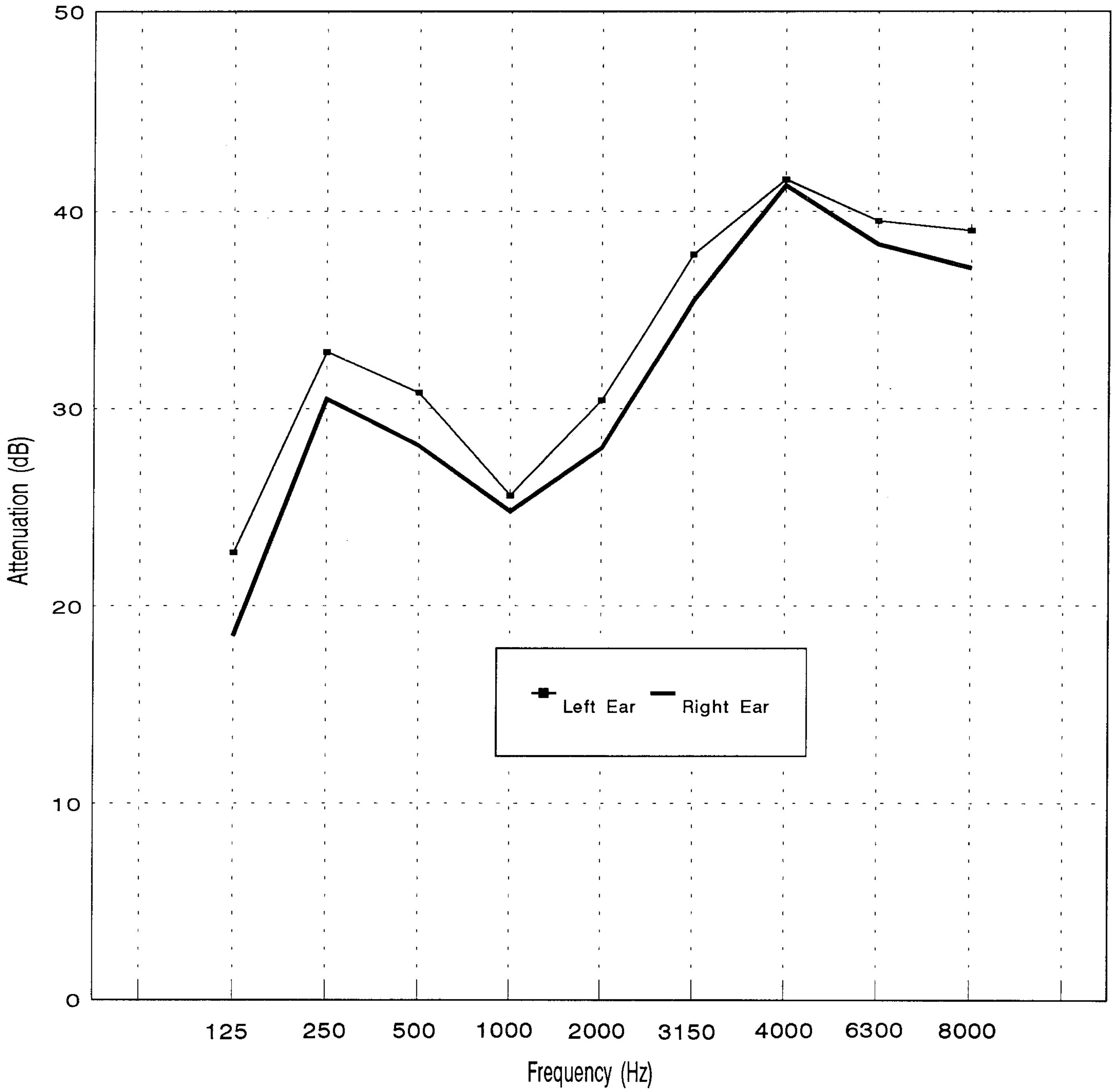

Figure 6. Comparison of left versus right earcup active/passive attenuation.

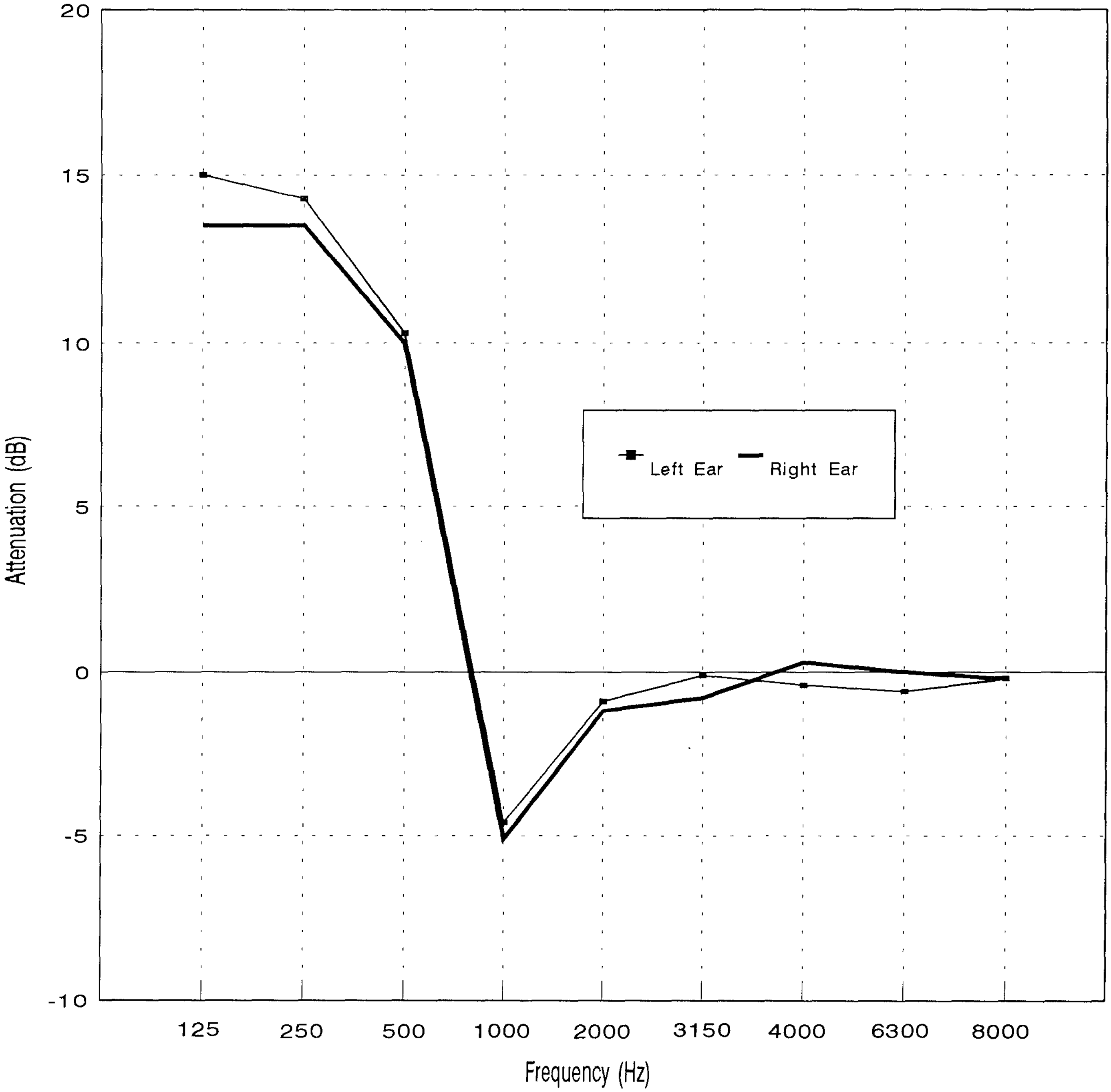

Figure 7. Comparison of left versus right earcup active attenuation.

Table 2. Mean Measurements of Speech Intelligibility (percentage test words correct). Standard deviations (SD) are shown in parentheses.

	Noise Level					
	95 dB		105 dB		115 dB	
ANR	off	on	off	on	off	on
Mean Percent TMRT* Words Correct	98.8	99.2	90.7	92.8	65.8	75.9
	(1.9)	(1.0)	(4.1)	(3.5)	(5.9)	(8.5)

*Tri-Word Modified Rhyme Test.

Table 3. Mean Measurements of Speech Intelligibility (percentage test words correct). Standard deviations (SD) are shown in parentheses.

	Noise Level					
	100 dB		110 dB		115 dB	
ANR	off	on	off	on	off	on
Mean Percent TMRT Words Correct (6 Ss)	95.2	95.7	74.3	85.8	----	----
	(4.0)	(2.2)	(8.7)	(4.6)		
Mean Percent TMRT Words Correct (3 Ss) 90 dB Speech	----	----	89.3	87.3	79.7	84.7
			(4.8)	(4.5)	(5.3)	(1.6)

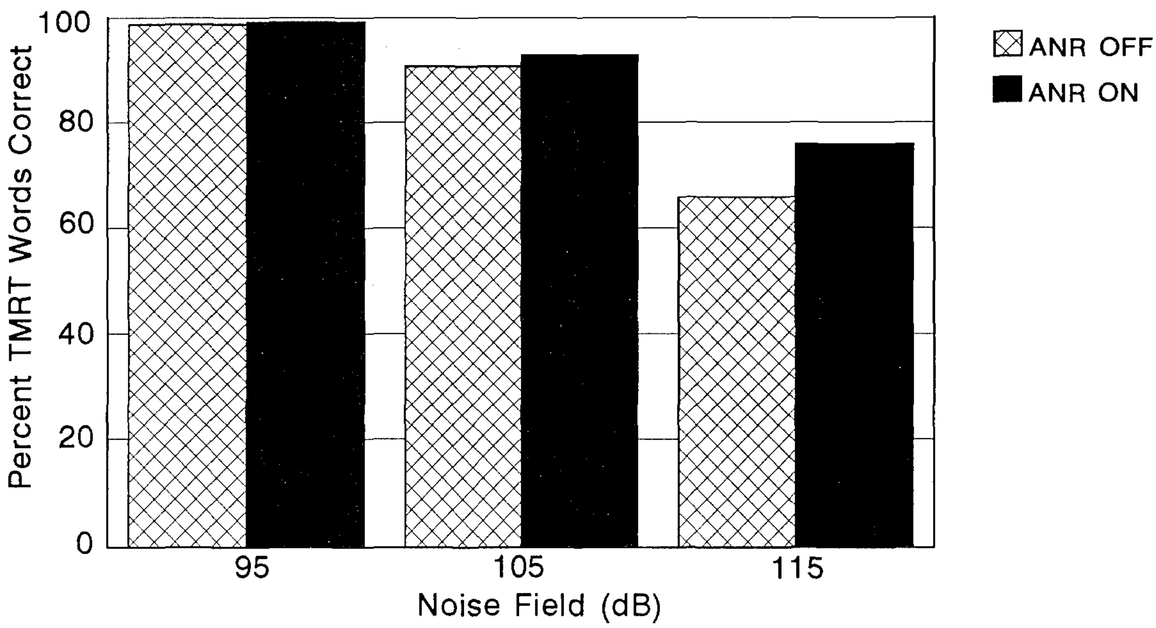

Figure 8. Mean percentage TMRT words heard correctly, ANR "off" and ANR "on," at the three noise-level conditions.

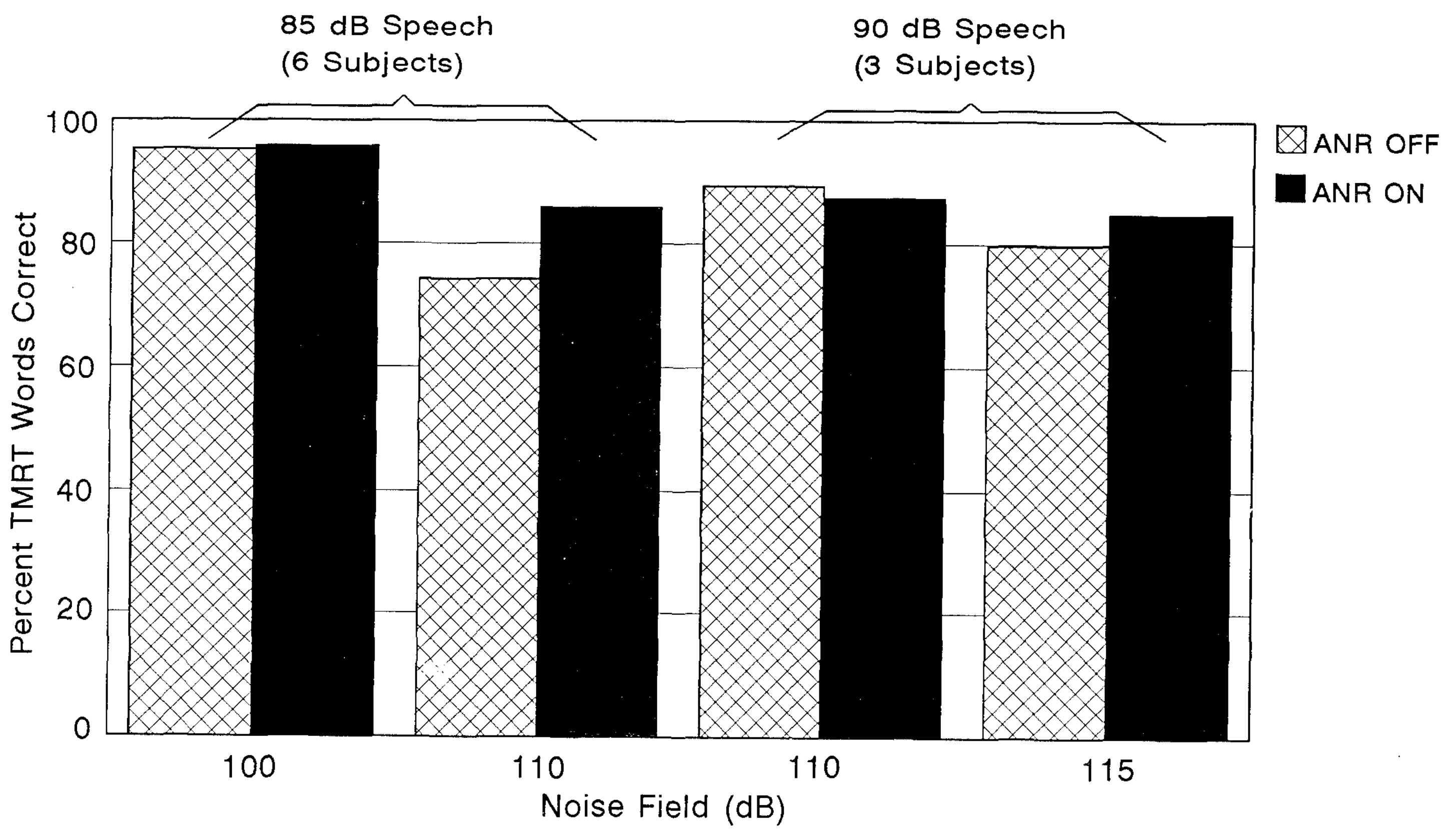

Figure 9. Mean percentage TMRT words heard correctly, ANR "off" and ANR "on," at the additional noise- and speech-level conditions.

Speech Intelligibility. At the two lower noise-level conditions (95 and 105 dB), there was no significant difference between speech intelligibility scores obtained with the AIR "on" and the AIR "off." There was, however, a significant difference (10%) between the "on" and "off" conditions at the 115-dB noise level as revealed by an ANOVA (F = 14.1, df (1,38), p < .001) with the "on" condition providing the better score.

Additional Speech Tests. The results of the additional speech tests conducted on limited numbers of subjects revealed an 11% improvement in intelligibility for the 110-dB noise-level condition (85 dB speech) and a 5% improvement in intelligibility for the 115-dB noise-level condition (90 dB speech). Not surprising, but encouraging in view of the small numbers of subjects, listener scores obtained at the 100-db noise-level condition fell between the scores obtained earlier at the 95- and 105-db noise-level conditions, and listener scores for the 110-db noise-level condition fell between scores obtained at the 105- and 115-db noise-level conditions. Listener scores obtained with ANR "off" and ANR "on" at the 90-db speech/115-db noise-level condition were 13.9% (ANR "off") and 8.8% (ANR "on") higher than the scores obtained earlier at the 85-db speech/115-db noise-level condition.

Experimenter Comments. At levels up to about 115 dB, no breakup of the signal occurred. When the ANR headset was in the "on" mode, diminution of the lower frequencies was very noticeable. While listening to speech signals when the ANR system was in the "on" mode, it was also readily apparent that there was a significant reduction in the middle to high speech frequencies. That is, the consonantal sounds were actually easier to hear (in some words) with the unit's ANR system switched "off." If the unit had been able to retain the presence of the higher frequencies while attenuating the lower frequencies, a greater difference in speech reception scores (between the "on" and "off" conditions) would have resulted.

CONCLUSIONS

The results of the evaluations demonstrated that active noise reduction technology could prove beneficial to sensor operators in P3-C acoustical environments. Improved low-frequency noise attenuation should enhance sensor operator performance in monitoring low-frequency acoustical signals and decrease the likelihood that sensor operators would sustain auditory fatigue during typical long-duration flights. The results were instrumental in the Navy's decision to proceed with further development and procurement of the ANR headset for use by sensor operators in the Navy's P3-C community.

Acknowledgments

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APPENDIX A

SAMPLE TMRT RESPONSE FORM (reduced)

NAME ______________ DATE ________ FORM <u>EX</u> TEST NO. SCORE ________

1

HOLD	COLD	TOLD
FOLD	SOLD	GOLD
DIP	SIP	HIP
TIP	LIP	RIP
PEN	HEN	MEN
THEN	DEN	TEN

2

SAVE	SAME	SALE
SANE	SAKE	SAFE
MASS	MATH	MAP
MAT	MAN	MAD
THAW	LAW	RAW
PAW	JAW	SAW

3

FIT	FIB	FIZZ
FILL	FIG	FIN
HANG	SANG	BANG
RANG	FANG	GANG
PIG	BIG	DIG
WIG	RIG	FIG

4

KIT	BIT	FIT
HIT	WIT	SIT
VEST	TEST	REST
BEST	WEST	NEST
HARK	DARK	MARK
BARK	PARK	LARK

5

RAY	RAZE	RATE
RAVE	RAKE	RACE
SEEP	SEEN	SEETHE
SEEK	SEEM	SEED
PIN	SIN	TIN
FIN	DIN	WIN

6

PIG	PILL	PIN
PIP	PIT	PICK
CANE	CASE	CAPE
CAKE	CAME	CAVE
FUN	SUN	BUN
GUN	RUN	NUN

7

BACK	BATH	BAD
BASS	BAT	BAN
MUST	BUST	GUST
RUST	DUST	JUST
DIN	DILL	DIM
DIG	DIP	DID

8

PEEL	REEL	FEEL
EEL	KEEL	HEEL
BEAN	BEACH	BEAT
BEAK	BEAD	BEAM
SHOP	MOP	COP
TOP	HOP	POP

9

KILL	KIN	KIT
KICK	KING	KID
BALE	GALE	SALE
TALE	PALE	MALE
DUG	DUNG	DUCK
DUD	DUB	DUN

10

PAT	PAD	PAN
PATH	PACK	PASS
CUP	CUT	CUD
CUFF	CUSS	CUB
TEAK	TEAM	TEAL
TEACH	TEAR	TEASE

11

HEAVE	HEAR	HEAL
HEAT	HEAP	HEATH
SILL	SICK	SIP
SING	SIT	SIN
WENT	SENT	BENT
DENT	TENT	RENT

12

PEACE	PEAS	PEAK
PEACH	PEAT	PEAL
PALE	PACE	PAGE
PANE	PAY	PAVE
BED	LED	FED
RED	WED	SHED

13

HEAT	NEAT	FEAT
SEAT	MEAT	BEAT
FILL	KILL	WILL
HILL	TILL	BILL
SUM	SUN	SUNG
SUP	SUB	SUD

14

WAY	MAY	SAY
PAY	DAY	GAY
COIL	OIL	SOIL
TOIL	BOIL	FOIL
PUFF	PUCK	PUB
PUS	PUP	PUN

15

SAG	SAT	SASS
SACK	SAD	SAP
LANE	LAY	LATE
LAKE	LACE	LAME
BUN	BUS	BUT
BUG	BUCK	BUFF

16

TAN	TANG	TAP
TACK	TAM	TAB
SAME	NAME	GAME
TAME	CAME	FAME
TOOK	COOK	LOOK
HOOK	SHOOK	BOOK

17

WICK	SICK	KICK
LICK	PICK	TICK
NOT	TOT	GOT
POT	HOT	LOT
DUCK	DUB	DUN
DUNG	DUG	DUD

APPENDIX B

PROTECTOR: PRU-57/P REAL-EAR DATES: 11-24-92 / 12-07-92

SUBJECT	125	250	500	1K	2K	3.15K	4K	6.3K	8K
M - 22	14	8	16	26	34	38	42	42	42
R.S.	12	6	16	20	32	40	40	42	44
1	10	10	16	28	34	42	42	44	42
M - 22	12	20	20	26	28	38	42	38	34
G.S.	12	22	18	28	34	40	46	42	40
2	14	20	18	28	32	36	44	38	40
M - 23	18	22	18	18	28	44	42	40	36
D.H.	10	18	16	18	34	40	42	40	36
3	16	18	18	26	26	36	42	38	42
M - 25	14	14	14	26	40	40	46	44	38
J.S.	8	16	16	28	36	38	40	40	42
4	10	16	16	26	38	38	42	40	38
M - 25	10	18	20	28	38	44	44	38	42
E.P.	16	20	22	22	30	36	40	38	38
5	16	18	16	26	32	38	44	40	40
M - 23	12	16	20	26	34	36	42	42	38
J.C.	16	22	24	24	32	34	40	36	42
6	18	20	22	32	34	40	46	38	40
M - 23	20	22	22	30	38	42	40	38	38
J.H.	18	22	22	24	34	42	42	42	42
7	12	18	18	26	30	38	40	42	40
M - 22	8	20	24	34	36	36	40	40	38
G.B.	14	20	20	22	30	32	36	42	44
8	10	20	24	20	36	34	42	46	42
M - 29	14	22	18	28	36	44	42	40	42
R.B.	10	16	22	24	38	46	38	40	36
9	16	20	18	26	36	46	42	44	42
M - 22	16	14	18	22	32	30	38	34	42
J.H.	16	14	14	22	32	34	38	38	42
10	14	22	16	28	34	32	42	40	36
MEAN	13.5	17.8	18.7	25.4	33.6	38.5	41.5	40.2	39.9
STANDARD DEVIATION	3.2	4.2	2.9	3.8	3.3	4.2	2.4	2.6	2.7

NRR= 16.7

APPENDIX C

PROTECTOR: PRU-57/P (L-OFF) MIRE DATES: 11-24-92 / 12-07-92

SUBJECT	125	250	500	1K	2K	3.15K	4K	6.3K	8K
M - 22	11	17	19	28	26	42	44	39	38
R.S.	8	21	19	29	34	41	44	37	38
1	10	21	19	32	32	41	44	37	36
M - 22	9	20	21	31	31	36	39	41	39
G.S.	10	19	20	30	33	38	43	42	39
2	10	18	19	29	31	39	44	36	35
M - 23	6	19	18	28	28	35	40	43	38
D.H.	4	19	19	28	27	37	36	39	41
3	7	19	18	29	25	34	35	36	32
M - 25	12	20	22	31	31	36	44	40	38
J.S.	9	19	23	31	32	38	42	39	39
4	9	18	24	31	35	38	43	37	37
M - 25	9	20	22	33	29	38	42	43	36
E.P.	9	23	19	32	32	40	43	41	37
5	10	22	24	34	33	40	42	42	37
M - 23	6	16	20	30	34	38	43	40	41
J.C.	7	16	18	30	31	38	45	42	41
6	10	17	20	31	32	39	44	41	41
M - 23	4	17	20	28	30	35	39	39	40
J.H.	5	17	20	30	33	38	41	40	41
7	3	14	19	29	33	40	42	38	41
M - 22	6	20	23	30	31	36	42	43	43
G.B.	7	18	20	29	32	34	41	40	42
8	5	16	21	28	33	35	43	41	42
M - 29	7	19	25	34	36	39	42	41	41
R.B.	6	18	22	32	38	41	44	42	41
9	6	20	22	33	37	41	45	42	41
M - 22	8	17	19	29	25	36	42	41	39
J.H.	9	19	22	30	28	40	42	41	41
10	8	19	18	27	27	35	40	40	41
MEAN	7.7	18.6	20.5	30.2	31.3	37.9	42.0	40.1	39.2
STANDARD DEVIATION	2.2	1.9	2.0	1.9	3.3	2.3	2.4	2.0	2.5

NRR= 19.5

PROTECTOR: PRU-57/P (R-OFF) DATES: 11-24-92 / 12-07-92

SUBJECT	125	250	500	1K	2K	3.15K	4K	6.3K	8K
M - 22	5	20	17	32	32	38	44	34	33
R.S.	4	19	19	31	34	39	45	35	37
1	6	19	17	32	32	37	43	38	37
M - 22	5	18	20	32	29	40	45	40	39
G.S.	4	20	18	30	31	39	46	39	37
2	7	18	17	31	30	36	43	37	36
M - 23	7	21	20	29	30	36	41	41	38
D.H.	5	19	18	30	30	36	40	39	37
3	7	20	20	27	33	37	43	37	36
M - 25	3	17	20	29	29	34	42	36	36
J.S.	3	17	18	30	28	32	38	39	37
4	5	19	16	28	26	33	42	37	38
M - 25	7	21	19	33	34	41	44	39	36
E.P.	6	24	18	35	33	39	43	37	38
5	7	20	18	33	36	40	42	39	35
M - 23	5	15	18	32	32	40	47	41	41
J.C.	8	17	20	29	29	41	47	42	40
6	9	17	18	29	28	34	43	42	39
M - 23	4	14	16	30	31	37	40	41	39
J.H.	3	11	17	28	26	36	42	38	40
7	1	11	18	28	30	36	43	40	39
M - 22	5	12	17	28	27	32	39	39	39
G.B.	4	12	18	26	25	29	31	37	35
8	4	16	18	31	27	37	38	41	36
M - 29	4	16	18	29	30	39	45	37	36
R.B.	3	14	18	30	36	43	45	40	39
9	2	16	19	31	31	37	44	39	36
M - 22	6	15	17	28	27	36	39	34	36
J.H.	6	19	19	28	24	34	40	36	37
10	6	13	17	29	23	34	39	36	36
MEAN	5.0	17.0	18.1	29.9	29.8	36.7	42.1	38.3	37.3
STANDARD DEVIATION	1.8	3.2	1.2	2.0	3.3	3.1	3.3	2.2	1.8

NRR= 17.7

PROTECTOR: PRU-57/P (L-ON) DATES: 11-24-92 / 12-07-92

SUBJECT	125	250	500	1K	2K	3.15K	4K	6.3K	8K
M - 22	26	31	31	26	27	42	43	39	39
R.S.	23	34	31	25	30	40	44	36	35
1	24	33	31	27	30	40	44	37	37
M - 22	25	32	32	29	31	40	41	40	40
G.S.	25	35	32	25	31	38	42	41	40
2	25	34	30	25	29	37	41	36	36
M - 23	23	32	29	21	27	37	41	38	37
D.H.	19	31	30	21	25	37	39	38	39
3	21	29	28	23	25	33	36	37	34
M - 25	25	35	31	27	31	37	41	36	34
J.S.	27	34	33	27	31	36	41	36	36
4	25	34	34	26	33	38	41	35	37
M - 25	23	34	33	29	30	37	44	43	35
E.P.	21	35	31	29	30	40	43	41	37
5	25	34	33	30	30	40	42	42	38
M - 23	21	33	30	26	32	37	41	42	42
J.C.	24	32	26	26	30	39	43	42	43
6	24	33	30	25	34	41	44	42	42
M - 23	17	30	28	23	27	34	39	40	41
J.H.	20	33	31	25	31	39	41	38	41
7	18	31	30	24	30	38	41	37	39
M - 22	23	35	32	25	32	36	41	42	41
G.B.	22	32	30	24	32	34	41	40	42
8	22	33	32	24	32	36	44	41	41
M - 29	23	35	32	28	36	39	42	41	42
R.B.	22	34	32	25	37	42	43	41	40
9	23	36	34	30	37	41	44	41	42
M - 22	23	30	28	25	24	37	41	44	41
J.H.	22	32	32	25	30	37	40	36	37
10	21	30	29	24	27	32	39	42	41
MEAN	22.7	32.9	30.8	25.6	30.4	37.8	41.6	39.5	39.0
STANDARD DEVIATION	2.3	1.8	1.9	2.3	3.2	2.5	1.9	2.6	2.7

NRR= 23.0

PROTECTOR: PRU-57/P (R-ON) DATES: 11-24-92 / 12-07-92

SUBJECT	125	250	500	1K	2K	3.15K	4K	6.3K	8K
M - 22	17	34	29	26	29	37	43	36	36
R.S.	18	32	31	26	34	38	44	35	38
1	18	30	28	25	30	37	43	39	37
M - 22	19	30	30	27	28	38	45	36	35
G.S.	16	31	29	27	30	36	44	38	36
2	21	30	27	26	28	34	42	34	35
M - 23	20	30	29	24	30	35	40	41	37
D.H.	19	31	26	24	30	35	40	40	35
3	19	33	28	22	32	37	41	39	37
M - 25	20	29	29	23	26	33	42	35	36
J.S.	17	30	26	23	25	32	39	36	35
4	20	29	28	22	24	32	41	35	37
M - 25	21	35	29	29	32	39	44	43	39
E.P.	21	36	28	28	30	38	42	39	40
5	19	35	29	27	35	39	41	40	36
M - 23	21	31	29	24	27	39	44	40	43
J.C.	20	29	27	24	27	39	47	40	39
6	20	29	26	23	28	33	43	42	39
M - 23	15	29	27	24	27	35	41	40	39
J.H.	17	29	30	24	24	36	41	39	39
7	16	29	27	23	27	34	42	40	40
M - 22	19	27	28	25	28	33	39	38	38
G.B.	16	29	29	21	23	27	31	38	36
8	17	30	29	26	25	35	37	39	37
M - 29	16	30	28	25	28	38	43	36	35
R.B.	17	32	28	25	33	41	44	39	36
9	17	30	30	28	30	36	43	39	35
M - 22	20	28	26	23	26	34	38	36	37
J.H.	19	29	28	25	22	32	38	38	36
10	21	28	26	24	22	32	37	38	36
MEAN	18.5	30.5	28.1	24.8	28.0	35.5	41.3	38.3	37.1
STANDARD DEVIATION	1.8	2.2	1.4	1.9	3.4	3.0	3.1	2.2	1.9

NRR= 21.6

APPENDIX D

SUBJECTIVE COMMENTS OF TEST SUBJECTS FOLLOWING SPEECH INTELLIGIBILITY TESTING

1. There was a definite improvement with the ANR "on"; the words were much clearer, especially at the higher noise levels. At the lower levels it was easy to hear with and without the ANR "on".

2. Some words, such as "sane" and "same" were hard to distinguish. The noise reduction is an outstanding addition to help hearing in high noise environments.

3. I could not tell a large difference between having the ANR "on" or "off." This could easily have been that I was too busy concentrating on incoming words. At the loudest level I had a very difficult time hearing the words (as I'm sure my score sheet will determine).

4. The clarity of sound was greater when the ANR unit was "on". There was a distinct difference in speech quality throughout the varying sound levels.

5. ANR "on" enabled me to concentrate more on the words being spoken. The loud noise vibration (body shaking) was still a problem which distracted concentration. With ANR "on" the words were clearer at the higher noise level. There was a distinct difference.

6. ANR "on" - very helpful at lower and mid-level; not as helpful at higher level. I could not notice a significant difference at the highest noise level with the ANR "on" or "off."

7. The noise level seemed lower with the noise reduction. I could hear the words a little better with the noise reduction "on". This improvement seemed to be better at the lower two noise levels. The loudest noise level seemed to "shake" my head and body making it harder to hear softer sounds, i.e., "h's" at the beginning of a word.

8. ANR "on" definitely improved the enunciation of words that sound similar. At high volume the ANR makes a big difference in speech reception and allows the subject to concentrate in a more relaxed state which makes concentration easier to maintain; in other words, it reduces the amount of distraction and increases the comfort of the ears and body.

9. Seemed that ANR helped eliminate some of the background noise. It seemed to be a noticeable difference. In particular the high frequencies seemed to attenuate better.

10. The speech was much more intelligible at low noise levels with the ANR "on." As the noise level increased, the difference between intelligibility with ANR "on" and ANR "off" decreased. At the highest noise level I could tell almost no difference. However, at the lowest level, the ANR drastically reduced background noise.

Comments of Additional Six Subjects
(Noise levels: 100 and 110 dB)

1. It was much easier to hear with the ANR device "on". The external noise was much less distracting. It almost seemed to raise the volume and clarity of the speaker.

2. With the noise reduction "on" the words seemed crisper/sharper, hence easier to understand. If completed, would be very useful in the fleet.

3. When the ANR was "off" for the louder noise levels, I could distinguish the words better. I think the ANR helped me to hear at the lower noise levels.

4. I feel that I was able to effectively block out background noise with ANR "off" so as to differentiate words. With ANR "on", the listening was not much easier. I noticed that I was better at distinguishing words by their endings rather than beginning letters.

5. With ANR, speech recognition was easier, not to an extremely large degree, but still noticeable. With no ANR, the amount of noise induced stress increased markedly.

6. I thought that the ANR made a big difference in speech clarity at the 110 dB noise level. It also aided clarity at the 100 dB noise level, but the difference was much more evident at the higher noise levels. In all cases, distinguishing the words became easier after the first 2 or 3 sets in each test. This seemed to give the ears time to adjust to the new noise level.

Comments of Additional Three Subjects
(Noise levels: 100 and 115 dB; Speech level: 90 dB)

1. Less clarity on words with ANR "on" - - but less noise. Better at the higher noise levels. With the ANR "off" more noise was heard at the lower sound levels, but better clarity. At 110 dB noise level, would rather have had ANR "off" for understanding speech; at the 115 dB noise level would rather have the ANR "on." At lower noise level no difference noted.

2. The volume of the speech with ANR activated increased, but the diction and clearness seemed to decrease. It was harder to distinguish between similar words than anticipated. The ANR did eliminate the background noise by quite a bit, which made less distraction.

3. The only difference I saw was with the ANR "off" in that it was more difficult to identify the beginning of the word rather than the end. The ANR allowed me to distinguish the first letter of the word more easily. The ANR was slightly more muffled at the higher noise level than at the lower noise level. Comfortable earphones.

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13. ABSTRACT *(Maximum 200 words)*
Sound attenuation and speech intelligibility evaluations were conducted on a modified active noise reduction (ANR) headset being considered for use by sensor operators in Navy P3-C aircraft. Measurements were obtained on 10 male ensigns in the Naval Aviation Flight Training Program. A comparison of the sound attenuation values obtained with the ANR "on" (combined passive and active attenuation) to values obtained with the ANR "off" (passive attenuation) revealed 10-15 dB greater attenuation at 125, 250 and 500 Hz, and 1-5 dB less attenuation at 1000 and 2000 Hz. Speech intelligibility scores obtained with the ANR "on" were 10% greater than scores obtained with the ANR "off" at the two highest noise levels (110 and 115 dB SPL). The results of the evaluations demonstrated that ANR technology could prove beneficial to sensor operators in P3-C acoustical environments. Improved low-frequency noise attenuation should enhance sensor operator performance in monitoring low-frequency acoustical signals and decrease the likelihood that operators would sustain auditory fatigue during typical long-duration flights. The results were instrumental in the decision to proceed with the further development and procurement of the headset for use by sensor operators in the Navy's P3-C community.

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